THE ROLE OF TRANSDISCIPLINARITY IN RESEARCH AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT
Sustainability problems are widely recognised as wicked problems. The scientific expertise needed to deal with multifaceted and complex sustainability problems requires innovation, creative thinking, action-orientated and transdisciplinary approaches. This chapter explores the transdisciplinary approach with sustainability lenses and highlights the need of transdisciplinary practice as one of the guiding principles of education for sustainability by bringing about mutual learning, collaborative research, and problem solving processes among academia, business, government and civil society. The concept of linking knowledge to action for sustainability requires a very different type of education to generate the knowledge that matters to people's decisions and education. From analysing the principles and different implications of the transdisciplinary approaches on both sustainability research and education and revising some implementation experiences on transdisciplinary education approaches for sustainability it is concluded, that transdisciplinarity has the potential to break the dominant fragmentary disciplinary thinking. Some of the assessments of transdisciplinary experiences suggest that there is a need to focus on education professionals training and on the revision of the best practices.

KEYWORDS
Higher education, knowledge co-creation, Transdisciplinarity, sustainability science

INTRODUCTION
In our world characterised as it is by rapid change, uncertainty and increasing interconnectedness, science is increasingly called on to contribute to the solution of persistent, complex, global problems. There is political agreement on the need to build awareness and develop strategies to deal with current societal global challenges, such as economic crises, climate change, desertification, deforestation,
environmental degradation, inequalities, wars and poverty eradication (United Nations, 2012) and in this global context, the idea of sustainability as the way forward to ensure quality of life, equity within and between current and future generations, and environmental health, has gained widespread international recognition.

Although the conceptualisation of sustainability remains controversial, and there are different perspectives and definitions of the term (Dresner, 2002), the academic approach to sustainability is to generate scientific knowledge, as well as other forms of knowledge, from different subject areas, such as social and environmental sciences, economics, ethics and politics.

Transdisciplinarity (Td) breaks away from this fragmentary disciplinary thinking (Ramadier, 2004) preserving the different realities to confront them in a controlled way, no longer searching for consensus but for articulations. The intellectual fluidity is also what possibly most clearly distinguishes Td from both multi and interdisciplinary inquiry. As multi refers to cooperation among epistemic stakeholders without intellectual cooperation and inter refers to cooperation through an integrative concept, Td refers to intellectual cooperation by ad hoc rules adopted for each individual case (Huutoniemi et al., 2010).

SUSTAINABILITY AND TRANSDISCIPLINARITY
Sustainability problems are widely recognised as wicked problems (Hodorn et al., 2006; Lawrence and Després, 2004; Klein, 2014; Seager et al., 2012; Rieckmann, 2012; Weik et al., 2011; Brundiers and Weik, 2010). As Norton (2005) conceptualises, sustainability problems typically exhibit five characteristics that are shared by wicked problems: difficulties in problem formulation, multiple but incompatible solutions, open-ended timeframes, novelty (or uniqueness) and competing value systems or objectives (Seager et al., 2012). In this sense, beyond the scope of the current industrial-age science, sustainability problems involve dealing with ambiguity, complexity, different stakeholders, views and values and are difficult to solve because of their evolving and moving nature. The scientific expertise needed to deal with these multifaceted and complex sustainability problems nature is in need of reform, so that it requires innovation, creative thinking and problem-driven, action-orientated and transdisciplinary approaches.

The concept of Td has also become aligned with sustainability in the most recent discourse on problem solving (Klein, 2014). Knowledge demands from society are about issues that call for change in societal practices. These can be complex matters, “where facts are uncertain, values in dispute, stakes high and decisions urgent. In such a case, the term ‘problem’, with its connotations of an exercise where a methodology is likely to lead to a clear resolution, is less appropriate” (Funtowicz and Ravetz, 1993, p. 744). The situation is not so much solved, as frequently attempted, by creating supposed teams of specialists in different areas, around a given problem. With such a mechanism one can only hope to achieve an accumulation of visions emerging from each of the participating disciplines. As Max-Neef stated “an integrating synthesis is not achieved through the accumulation of different brains. It must occur inside each of the brains and, thus, it’s needed to orient higher education in a way that makes the achievement of such a purpose possible” (Max-Neef, 2005, p. 5). The ‘problem’ situation demands a problem-solving strategy that is achieved through a transdisciplinary orientation in research, education and institutional aims (Jagér, 2008). With sustainability as its normative model, scientific activity is demanded to be an “agent of change”, adopting problem-solving approaches and innovation for society (Leuphana, 2012). It raises the need to efficiently consider Td as one of the guiding principles of education for sustainability.

Agreement exists on the need to develop new ways of knowledge production and decision-making in order to deal with sustainability challenges (Lang et al., 2012). A critical element of sustainability science is the engagement of different actors from outside academia into research processes. This allows the integration of the best knowledge available, the reconciliation of different values and political interests, and taking ownership of problems and solutions. In this sense the multidisciplinarity, interdisciplinary and transdisciplinary aspects of sustainability have been widely acknowledged as the best means to deal with sustainability.

Participatory, interactive, transdisciplinary, transacademic, collaborative and community-based research approaches are referred as appropriate means to meet both the requirements posed by real-world problems as well as the goals of sustainability science as a transformational academic discipline (Lang et al., 2012). The commonality of these approaches can be found in the establishment of widened participation and research collaborations amongst scientist and non-academic stakeholders from business, government, and the civil society to address sustainability challenges. The next sections focus on the need for, and the principles of, transdisciplinary approaches.

DEFINING TRANSDISCIPLINARITY
After 40 years of intensive scholarly discourse a universally accepted definition is
Beyond cross-disciplinary methodologies (Scholz and Marks, 2001) Òd is transcending, transgressing, and transforming. It is theoretical, critical, integrative, and restructuring but, as a consequence of that, it is also broader and more exogenous (Hadorn, 2008). Thus by bringing about mutual learning, collaborative research, and problem solving among business, government and civil society, Òd can serve as an important guiding concept for sustainability science and practice. Òd emerged to counteract the tendency of disciplines to separate knowledge into artificial compartments (Russell et al., 2008). The central challenges of transdisciplinarity are:

- Crossing boundaries: between disciplines, between academia-society, individuals-companies, between forms of generating knowledge and communication and between educational systems;
- ‘Not for society, but with society’ (INIT, 2012): Moving from a conception of research on or for society, to research with society;
- Co-production and integration of „knowledge” : related to the resolution of a complex and evolving problem, it is considered the main cognitive challenge of transdisciplinary process. A problem solving process moves to a process-driven approach of problem definition and problem managing.

FROM DISCIPLINE TO TRANSDISCIPLINE

Different approaches exist between disciplinarity and transdisciplinarity (see Table 1, Figure 1).

Disciplinarity is about a mono-discipline, which represents specialisation in isolation. In both multidisciplinarity and pluridisciplinarity, disciplines are considered as being complementary and juxtaposed in the process of understanding phenomena, taking into account only part of each model, in order to maintain coherence. This approach highlights the different dimensions of the object studied and respects the plurality of points of view, searching for consensus.

Interdisciplinarity differs from multidisciplinarity in that either it constructs a common model for the disciplines involved, or transfers models or tools from one discipline to another based on a process of dialogue between disciplines, with the purpose being to create a new approach, as new needs and professions have emerged (e.g. biotechnology, cheminformatics, nuclear medicine). Interdisciplinarity, like multidisciplinarity, avoids paradoxes and having to solve them, both approaches are fragmented in dealing with disciplinary thinking.

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Table 1. Characteristics of multi-, pluri-, inter- and transdisciplinarity

Transdisciplinarity goes a step further and breaks away from this type of thinking, since the objective is to preserve the different realities and to confront them in a controlled way, no longer searching for consensus but for articulations. The aim is thus to avoid reproducing fragmentary models typical of disciplinary thinking (Ramadier, 2004) and also to take into account the real-life thinking.

Figure 1. From discipline to transdiscipline (adapted from Ramadier, 2004).

THE PRINCIPLES OF TRANSDISCIPLINARITY FOR RESEARCH AND EDUCATION

Sustainability research and transdisciplinary research strongly overlap and they are often used interchangeably (Kates et al., 2001). In this sense transdisciplinary aspects of research for sustainability also encompass the different academic disci-
plines, and it is based on participation and collaboration between different actors and stakeholders. Td is also seen as an ambiguous and contested concept with a variety of terminologies and definitions and diverse research approaches used. Yet where concepts or ideas are not properly defined, the risk is, that a rather shallow interpretation prevails, a fate that paradigmatically befalls the notion of sustainability. The likely damage that can occur with such a mainstreaming is, that the true challenges of transdisciplinary collaboration are underestimated (Jahn et al., 2012).

In the earlier conceptualisations Td was understood as a superior form of interdisciplinarity with its aim being to develop an overarching framework for complex problems that needed to work across disciplines.

By the end of the last century new definitions of Td as a methodology emerged. This was mainly because of the need to facilitate a broader scientific and cultural dialogue within the new complexity view and the need to deal with real-life problems such as sustainability (Klein, 2004). Thus Td is a reflexive, integrative, cooperative, method-driven process that aims to (Lang et al., 2012):

a) Identify the solutions to or transitions of relevant societal problems and concurrently of related scientific problems by integrating knowledge from various scientific and societal bodies of knowledge;

b) Enable mutual learning processes amongst researchers from different disciplines (from within academia and from other research institutions) as well as actors from outside academia, on an equal basis; and

c) Create and integrate knowledge that is solution-orientated, socially robust, and transferable to both the scientific and societal practice, also considering that Td can serve different functions, including capacity building and legitimisation.

Td research is also considered a form of action research. Participation and learning circles have to start from the beginning where the scientist acts as an “observer of the common learning process” (Häberli et al., 2001). The concept of linking knowledge to action for sustainability (Kates et al., 2001) obviously requires a very different type of research and education to generate the knowledge that matters to people’s decisions, create an education that enables students to be visionary, creative, and rigorous in developing solutions, and leave the protected space of the classroom to confront the dynamics and contradictions of the real world (Wiek et al., 2011). Also, Td raises the question not only of solving problems, but also of problem choice and definition (Klein, 2004), where different approaches are needed depending on the kind of problems.

FROM TRADITIONAL KNOWLEDGE BOUNDARIES TO KNOWLEDGE CO-CREATION

Over the last decades many scientists have argued that our relationship with a complex world requires complex thought. Max-Neef (2005) suggested that knowledge should be organised around hierarchical systems at four levels: purposive (values), normative (social systems design), pragmatic (physical technology, natural ecology, social ecology) and empirical (the physical inanimate and animate worlds, and the human psychological world). As Figure 2 shows, this hierarchy corresponds with the pyramid of Td, where the four levels (purposive, normative, pragmatic and empirical) are interconnected, including horizontal principles within levels (interdisciplinarity) and also vertical principles between levels (transdisciplinarity).

Figure 2. Pyramid of transdisciplinarity (adapted from Max-Neef, 2005)

Furthermore, in the context of research, three types of knowledge are needed to accomplish a Td research process:

1. Systems knowledge: related to the origin and development of problems. It seeks to identify causal relations, the interconnections and complexity existent within systems;

2. Target knowledge: this makes reference to the knowledge and development of the required or desired system status to be reached, e.g. in the identification of the need for change, desired goals and better action;

3. Transformation knowledge: is about the means to achieve a transformation,
in relation to the technical, social, historical, legal and cultural dimensions amongst others. It is related to the means needed to transform existing action into new directions.

The domain of Td research is situated at the interface between these three types of knowledge, which are seen as to be complementary. As Figure 3 shows, Gazilusoy and Boyle (2013), linked the pyramid of Td with the three types of knowledge as part of the transdisciplinary research processes.

![Figure 3. Relationships between the pyramid of transdisciplinarity and the three types of knowledge of the transdisciplinary research (Gazilusoy and Boyle, 2013)](image)

Systems knowledge is mainly acquired from the two bottom levels, which provide the empirical information necessary to understand phenomena and situations. Target knowledge involves visioning for a new system status, and is mainly obtained from the normative and the values levels of the pyramid. Transformation knowledge does not directly link to any of the levels of the pyramid since the means to achieve this transformation are amorphous and vary according to the problem or situation being addressed. It is therefore generated through the reflection and synthesis of knowledge from all four levels of the pyramid.

**TRANSDISCIPLINARITY IN HIGHER EDUCATION FOR SUSTAINABILITY**

Spangenberg (2011, p. 275) suggested there is a distinction between the “traditional disciplinary-based science for sustainability (descriptive-analytical) and the transdisciplinary science of sustainability (transformational)”. In other words, sustainability science in its transformational mode seeks broad transdisciplinary participation throughout research and practice, focused on solving sustainability problems. Regarding complex, actual “wicked problems”, Kates and colleagues maintain that sustainability research and transdisciplinary research strongly overlap and are hence considered interchangeable (Kates et al., 2001).

Without having reached the 1997 Locarno Declaration aim to devote 10 percent of teaching time in each discipline to Td (Locarno International Congress, 1997), the inter- and transdisciplinary approach still experiences promising advances in education and research. It does at the same time face institutional, epistemological and methodological barriers (Darbellay, 2014). Therefore, beyond the university, transdisciplinary education can occur in situ, in the workplace and in projects with community stakeholders (Klein, 2008). In this sense the most complex challenge according to Niculescu (2002) is the teaching of education professionals and developing appropriate pedagogy.

In spite of this the business of education has traditionally been just the transmission of knowledge. However the future has to be more dynamic. Inter- and transdisciplinary researchers offer new academic profiles for the multiple and hybrid identities that take the risk of working on the boundaries of disciplines. To encourage this, the skills associated with them should be supported, enhanced and valued (Darbellay, 2014). In different sets of transdisciplinary skills (Derry and Fischer, 2006; Pohl et al., 2008), the underlying theme is cognitive flexibility, manifested in a willingness to see beyond one’s own discipline and to the integration of knowledge. Of course, the authors warn that nobody will be expert in all areas and other members and teams are needed to fill skill gaps. Additionally, the concept of linking knowledge to action for sustainability (Kates et al., 2001) has been reiterated during the last decade in the discourse of Td (Komiyama and Takeuchi, 2006; van Kerkhoff and Lebel, 2006, cited in Wiek et al., 2012), in alignment with research methodologies as action research, participatory future studies, etc.

Td education and research methods developed in different universities (Scholz and Tietje, 2002), have required innovative methods that can allow knowledge integration in four differentiated dimensions:

1. Different disciplines in order to establish interdisciplinarity (humanities, social and natural sciences)
2. Different systems and compartments to create holistic approaches (such as water, soil, air)
3. Different qualities of thought (such as intuition and analysis)
4. Different interests of stakeholders involved

Td or forms of Td have been introduced in many different formats in curricula. As there is no systematic compilation of models and practices (Klein, 2008), some
initiatives and practices have been collected from network websites, publications from conferences, and books:

**Compulsory courses in undergraduate programs**
Minor Sustainability in Humanities, Leuphana University, Germany;
First-year course: Society, Science and Culture, Faculty of Education-GRET, UAB, Spain;
Ecosystem Health Program, University of Western Ontario, Canada.

**Master programs**
Graduate Studies and Continuing Education in Transdisciplinarity, ETH-UNS, Zurich;
Master in Sustainable Development, University of Basel, Switzerland;
Master’s program Sustainability Science, Leuphana University, Germany;
Master in Science and Technology for Sustainability, UPC-BarcelonaTech, Spain.

**Doctoral programs**
Transdisciplinary Ph.D. Program, Stellenbosch University, South Africa;
Transdisciplinarity course at Doctoral school “European Paradigm”, Babes-Bolyai University, Romania.

**Winter or summer courses**
“Science Meets Practice” Winter School, Competence Center Environment and Sustainability-CCES, Wissikon, Switzerland;
Td Summer School, Leuphana University.

**Workshops**
Training courses or activities for professionals and other academic modalities, Wageningen Initiative for Strategic Innovation, Wageningen UR, Netherlands;
Intensive participatory design process led by the Interdisciplinary Research Group on Suburbs-GrRBA, Faculté Aménagement, d’Architecture, d’Art et de Design, Université Laval of Québec City, Canada.

A few universities have implemented an experiential learning environment that affects the whole learning and campus living of students including the Institute for Sustainability and Technology Policy, Murdoch University, Australia; Leuphana University of Luneburg, Germany; and the School of Sustainability, Arizona State University-ASU, USA.

Generally speaking, academic programmes tend to be located within discipline-dominated institutions rather than autonomous institutions. Often when entering Td, researchers enter unfamiliar grounds for the production of scientific knowledge (Hadorn et al., 2006).

At the graduate level, Fry (2003) urges an increase in the availability of supervisors in pertinent methods, more teamwork, a wider range of courses and seminars, and greater opportunities to mix with students of different knowledge cultures.

Other areas for improvement include collaboration between academics and practitioners, joint problem definition, and the guidance of students to participate successfully in collaborative, real-world projects. In the AGB project, students strongly felt the need for additional research to connect research on how people learn with research on pedagogy, or how to teach people how to learn (Holden et al., 2008).

Nevertheless, operationalising the goals of the field, developing the necessary competencies, and seeking novel partnerships between society and the academy will position academic institutions to impact on the transition towards sustainability (Leeuw et al., 2012).

**CONCLUSIONS**
In a context of complex real-life scenarios Td emerges as a critical method-driven approach to the progress and development of the new academic field of sustainability science. Td as a research approach spans across disciplinary boundaries to develop a holistic approach with society. The aim is to search for articulations and thus to avoid reproducing fragmentary models typical of disciplinary thinking and also take into account real-life societal problems. It allows a dialogue and collaboration to be established between disciplines and society, where mutual and transformative learning can be fostered, which can in turn provide the management of solutions to current sustainability challenges that society is facing.

The largely declared need for universities to prioritise their pragmatic social mission of addressing problems coming from society (CERL, 1982) towards a common social purpose should be the key to address the transgression path through a “socially robust knowledge”. In this sense, the search for articulations of different realities has to be present in the higher education for sustainability framework (curriculum structure, faculty competences, pedagogical approaches, etc.). This opening movement can also be seen in the researchers’ transformed and hybrid identities that lie between and beyond disciplinary boundaries and participate in the development of a new thought style.
This chapter focuses on the potential of transdisciplinarity to break the dominant research and education approach of fragmentation and to avoid reproducing fragmentary models typical of disciplinary thinking. An unanticipated analogy emerged between the kind of additional responsibility central to the Td experiences and the additional responsibility that is central to moving toward sustainability. Issues that point the way to transdisciplinarity for sustainability are the revision of the best practice and best thinking on teaching and learning possibilities. The further aim is to integrate and to co-create between disciplines, between researchers and practitioners, and between research-based knowledge and action.

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